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THE EFFECTS OF RF ENERGY

ON

THE XM6 AND XM8 EBW SQUIBS

15 January 1963



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THE EFFECTS OF RF ENERGY
ON
THE XM6 AND XM8 EBW SQUIBS

by

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ABSTRACT

The XM6 and XM8 exploding bridgewire squibs were tested to determine their susceptibility to radio frequency energy. In the course of the tests, both types of squibs were fired with RF energy, using an impedance matching network to effect efficient transfer of power through a transmission line. No firings were obtained where the power was broadcast. As expected, the energy levels required for initiation were much higher than that required for conventional squibs.

THE EFFECTS OF RF ENERGY ON THE XM6 AND XM8

EBW SQUIBS

I. INTRODUCTION

Recent increases in the power output of missile radar systems have caused great concern in the field of squib research. Conventional bridgewire-type electric squibs are susceptible to the high strength electro-magnetic fields produced by these radar systems and other modern high frequency transmitters. The probability of initiation when squibs are exposed to these fields depends on a number of factors, including the energy radiated by antenna attached to the squib and the wavelengths of the energy producing the field. These sensitive squibs are also subject to initiation by the static charge that may accumulate on the squib case or the igniter case or by any accumulated electric charge that may produce an arc through the explosive charge in the squib.

These and other potential hazards, such as the accidental application of current to the squib circuit, have caused squib developers to direct their attention toward producing squibs that are more or less unaffected by these conditions. These efforts have resulted in the development of the exploding bridgewire (EBW) type squib. The functioning of this squib requires that enough energy be applied to the bridgewire to cause it to literally explode. Not all EBW squibs are assembled in the same way. Some have the bridgewire embedded in a relatively insensitive explosive charge while others have the bridgewire entirely removed from the charge.* All development testing of the EBW squibs had been done with either d.c. or 60 cycle a.c. power. Thus, no prior knowledge of their response at radio and radar frequencies existed even though they were specifically developed to be as nearly impervious as possible.

II. TEST PROCEDURE

The XM6 (Fig. 1) and the XM8 (Fig. 2) are two EBW squibs that have been subjected to certain RF tests. Both of these have the pyrotechnic charge separated from the bridgewire and enclosed in a Faraday shield. The XM6 has two posts through a ceramic plug, with the posts connected by a 2 mil gold alloy bridgewire which is in contact with the ceramic and is coated with an explosive material. Initiation requires enough energy to cause the explosive-coated bridgewire to detonate and pierce the metal shield containing the pyrotechnic. The XM8 squib differs from the XM6 in that it has no explosive material in contact.

* For a complete description of the XM8 Squib, refer to U. S. Army Missile Command Report No. RK-TR-62-6, 26 October 1962, "Development and Functional Characteristics of the XM8 Squib."

SQUIB, ELECTRIC: XM6

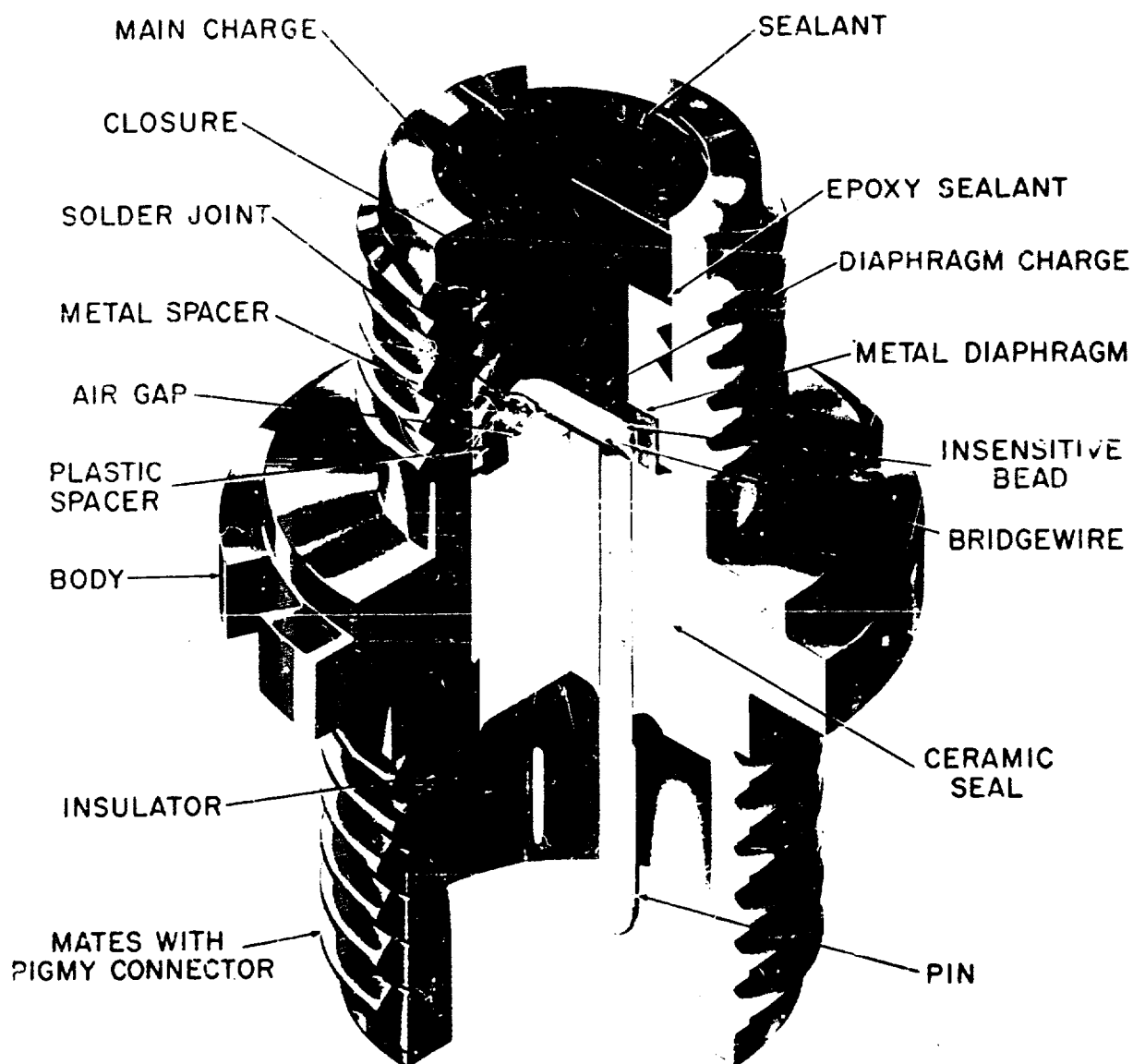


Figure 1

XM8 SQUIB

PYROTECHNIC

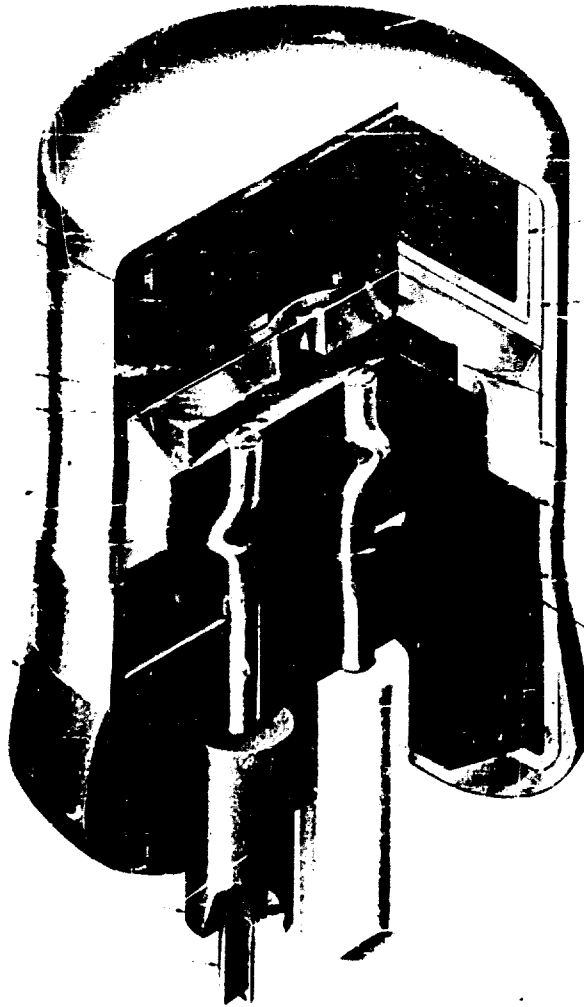
INSULATION
BRIDGE WIRE

CASE

WATERPROOF
COATING

LEAD WIRE
INSULATION

LEAD WIRE



METAL
SPEAR SPACER

CUP WITH
DIAPHRAGM END
FORMS
FARADAY SHIELD
WITH CASE

AIR SPACE

SPACER

SEALANT

PLUG

AIR GAP

Figure 2

with the bridgewire, and the plug is made of phenolic material instead of ceramic. The size and material of the bridgewire are identical to those of the XM6.

These two types of squibs were subjected to tests to determine their susceptibility to RF energy. The tests were conducted on one VHF frequency (143 mc.) and one HF frequency (3.7 mc.). The power levels used were on the order of several hundred watts.

The first work was performed at 143 mc. with transmitting and receiving antennas. The transmitter was loaded into the transmitting antenna delivering approximately 700 watts output, and a live XM6 squib was connected directly across the receiving antenna terminals. The first trials were made to ascertain if the squib could be dudded through simple melting of the bridgewire. It was known that the squib could not be actually fired because it is designed to fail safe under these conditions. At no distance could the XM6 squib be dudded. This was not unexpected. A dipole receiving antenna can be considered as a generator with an internal impedance of approximately 70 ohms. Obviously such a generator will deliver very little power to a 0.15 ohm load, which is the bridgewire resistance of the XM6 squib.

The next logical step was to try to design an impedance transforming circuit which would permit efficient power delivery to the bridgewire. The required values of components of LC circuits are so small at VHF frequencies that the most practical approach to matching networks is to use transmission lines as circuit elements. Impedance matching is frequently accomplished by matching stubs on the transmission line from the antenna to the load. In this case, however, the ratio of the impedance mismatch was so great that this technique was impractical. It was finally determined, through experimentation, that two one-quarter wavelengths of transmission line in series with the load (squib) would afford the best approach (Fig. 3). Using this arrangement and the receiving

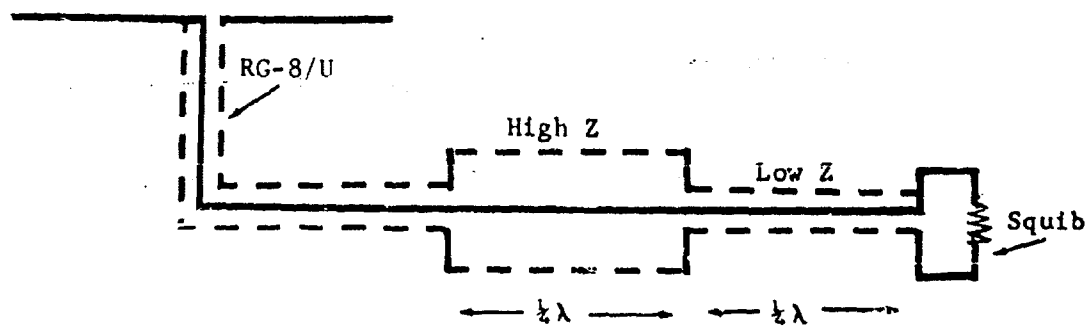


Figure 3

antenna placed at distances up to 3 wavelengths (approximately 18 feet) from the transmitting antenna, the XM6 squibs could readily be dudded. As before, the transmitter was delivering approximately 700 watts to the transmitting antenna. At no distance could any of the squibs be fired.

From these tests it was evident that getting power to the squib in large amounts could be accomplished only by coupling directly from the transmitter to the squib. Since the output impedance of the transmitter was 52 ohms, it would again require an impedance transforming network to deliver power efficiently to the squib. Matching networks to handle large amounts of power at VHF frequencies are especially critical due to the previously mentioned facts. Therefore, it was decided to shift the operating frequency to a low frequency in the HF range. The 3.5 to 4 mc. region was selected since it was the lowest frequency that the available equipment would produce. Component values for various types of networks were computed and found to be impractical because of the tremendous impedance ratio (346:1).

It was finally decided to use inductive coupling with series resonance in both the primary and secondary circuits (Fig. 4).

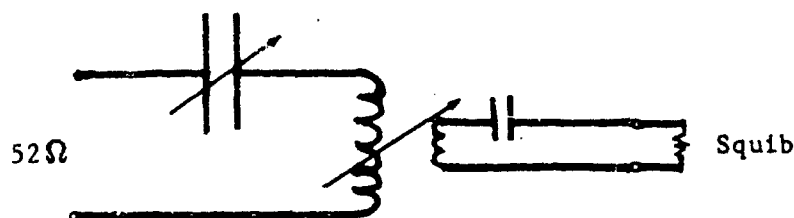


Figure 4

In view of the available component values, an operating frequency of 3.65 mc was selected, and a dummy load was devised with electrical characteristics similar to those of the squibs being studied. The load was immersed in a measured quantity of distilled water. Power was applied for a period of one minute, and the temperature rise of the water was noted. A calorimeter was used to determine the actual power delivered to the load. This power was calculated to be approximately 430 watts, which is equivalent to 80 amperes of current through the squib bridgewire. XM6 squibs substituted for the dummy load were easily dudded but would not fire.

It was found that dudged XM6 squibs could be initiated by the application of the high RF voltage existing across the primary of the matching network. This voltage was on the order of several thousand volts, and the dudged XM6 would arc internally until eventually initiation was achieved. It must be mentioned, however, that an undudged XM6 subjected to the same potential would neither dud nor fire.

Similar tests were performed on XM8 squibs. Four were successfully fired when connected to the circuit shown in Figure 4. The lead-to-lead resistances of these specimens were measured after firing and found to be 70, 45, 16, and 14 ohms, respectively. Close examination of the base after firing disclosed that the area between the posts which normally support the bridgewire had experienced a change which may have been a carbonization and, thus, a low resistance path for the RF current. Several disassembled specimens were subjected to the RF power and observed. When the power was applied, the area between the posts heated, turned a bright red, then flamed briefly. The burning continued as power was applied and the lead-to-lead resistance decreased to the order of 1 ohm. It was concluded that the plastic base of the XM8 squib was conducting due to the change wrought by the RF current, and the resulting heat was igniting the pyrotechnics in the squibs. This chain of events occurred after the bridgewire was burned away under the initial application of power.

Another group of 35 XM8 squibs was later tested under similar circumstances. Subsequent disassembly and examination revealed the following:

1. In all the squibs, the area between the posts had the characteristic brown, scorched appearance.
2. In some, the outline of the bridgewire showed in the scorched area.
3. The holes in the plastic spacers were scorched and smoky and some had particles of wire embedded in the plastic.
4. The diaphragms had brown smudges in the areas corresponding to the holes in the spacers, and some had small holes through the diaphragms.

It was found that the XM8 squib can be readily initiated when a high RF voltage, such as that found across the network primary, is applied between the leads and the case.

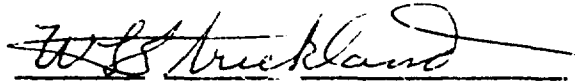
III. CONCLUSIONS

The EBW squib can be initiated when large amounts of radio frequency power are delivered to the bridgewire. A lesser amount will dud the squib. The squibs can also be initiated with high voltage radio frequency energy even after they have been duded. There exists a high degree of safety, however, due to the relatively high levels of energy required for initiation and the large impedance mismatch between transmitter and squib.

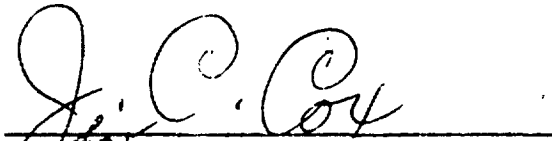
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